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Spectroscopic and photometric observations of dwarf nova superoutbursts by the 3.8 m telescope Seimei and the Variable Star Network

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Abstract

We present spectroscopic and photometric observations of 17 dwarf-nova superoutbursts obtained by KOOLS-IFU mounted on the 3.8 m telescope Seimei at the Okayama Observatory of Kyoto University and through the Variable Star Network collaboration (VSNET). Our spectroscopic observations for six outbursts were performed within 1 d of their optical peak. 11 objects (TCP J00590972+3438357, ASASSN-19ado, TCP J06073081−0101501, ZTF20aavnpug, ASASSN-19ady,

MASTER OT J061642.05+435617.9, TCP J20034647+1335125, ASASSN-20kv, ASASSN-20kw, MASTER OT J213908.79+161240.2, and ASASSN-20mf) were previously unknown systems, and our observations enabled quick classification of their transient type. These results illustrate that the Seimei telescope has the capability to conduct quick follow-up observations of unknown transients. Our photometric observations yielded that 11 of the objects are WZ Sge-type dwarf novae and their candidates, and the other six are SU UMa-type dwarf novae and their candidates. The He II 4686 Å emission line was clearly detected among ASASSN-19ado, TCP J06073081−0101501 and MASTER OT J213908.79+161240.2, the association of which with a spiral arm structure in an accretion disk has been suggested in previous studies. Our result suggests that a higher-inclination system shows a stronger emission line of He II 4686 Å, as well as larger-amplitude early superhumps.

Key words: accretion, accretion disks — novae, cataclysmic variables — stars: dwarf novae

1 Introduction

Cataclysmic variables (CVs) are a close binary system composed of a primary white dwarf (WD) and a secondary low-mass star. The secondary star fills up its Roche lobe, transferring mass into the primary Roche lobe through the inner Lagrangian point L_1. Dwarf novae (DNe) are a subclass of CVs which possess an accretion disk and show recurrent outbursts (for a review of CVs and DNe, see Warner 1995 and Hellier 2001).

U Gem-type DNe show normal outbursts, producing typically a 2–5 mag brightening for a few days. The mechanism of normal outbursts is understood as the thermal instability in an accretion disk (Osaki 1974; Meyer & Meyer-Hofmeister 1981). SU UMa-type DNe, one subclass of DNe, are characterised by superoutbursts. Superoutbursts are generally longer and brighter than normal outbursts. Superhumps are observed during a superoutburst, which are 0.1–0.5 mag variations with periods a few percent longer than the orbital one. Superoutbursts are explained by the thermal–tidal instability model (Whitehurst 1988; Osaki 1989; Hirose & Osaki 1990). WZ Sge-type DNe form a subclass of SU UMa-type DNe, showing mainly superoutbursts every 5–30 yr, and seldom normal outbursts due to their low mass-transfer rates (Osaki & Meyer 2002; Kato 2015). WZ Sge-type DNe are characterized by early superhumps, and part of WZ Sge-type DNe shows rebrightenings. An early superhump is a double-wave modulation observed in an early phase (1–10 d) of a WZ Sge-type DN superoutburst (Kato 2015). It is widely known that the period of an early superhump is almost identical with that of an orbital one, with less than $\leq 0.1\%$ difference (Ishioka et al. 2002; Kato 2002). Rebrightening is an outburst following a main superoutburst before returning to quiescence, the origin of which is still poorly understood (Richter 1992; Kato et al. 1998; Hameury et al. 2000; Osaki et al. 2001; Meyer & Meyer-Hofmeister 2015).

Clarke, Bowyer, and Capel (1984) and Hessman et al. (1984) studied the evolution of optical spectra from quiescence to whole outburst cycle in SS Cyg. Quiescence flat spectra, dominated by Balmer and some He I emission lines, are replaced by bluer continuum and narrower absorption lines during an outburst (see examples in Morales-Rueda & Marsh 2002). This is because, during a DN outburst, the entire accretion disk becomes optically thick and the accretion disk outshines the whole system (Horne & Cook 1985). More specifically, due to foreshortening and limb-darkening effects, the strength of absorption strongly depends on the inclination of a system; a higher-inclination system tends to show stronger emission components (Marsh & Horne 1990; Warner 1995, and references therein). In fact, the highly inclined and eclipsing IP Peg does not show absorption lines even during its outbursts (Piche & Szkody 1989). In Z Cha, Honey et al. (1988) noted that the difference in optical spectra between normal outbursts and superoutbursts is the strong enhancement of He II 4686 Å and C III/N III Bowen blend in superoutbursts, which would reflect the difference of outburst energy.

The spectral evolution during WZ Sge-type DN superoutbursts has been well studied in WZ Sge (Baba et al. 2002; Nogami & Iijima 2004), GW Lib (Hiroi et al. 2009; van Spaandonk et al. 2010), EZ Lyn (Isogai et al. 2015), and SSS J122221.7−311525 (Neustroev et al. 2017). However, due to the long outburst cycles and a small number of known WZ Sge-type DNe, systematic analyses and comparisons of the spectra during WZ Sge-type DN outbursts have been a challenge. In the superoutburst spectra of WZ Sge-type DNe, along with Balmer and He I series, high excitation lines such as He II 4686 Å and the C III/N III Bowen blend tend to be observed more frequently than in normal outbursts (Baba et al. 2002; Nogami & Iijima 2004; Hiroi et al. 2009; Kato 2015, and references therein). Especially in the case of the He II 4686 Å emission line, Baba et al. (2002) and Kuulkers et al. (2002) found a possible association between the early superhumps and the spiral arm structure in the accretion disk, which was obtained through the Doppler tomography of He II 4686 Å. The presence of a spiral arm during a DN outburst is also observed in SS Cyg (Steeghs 2001), U Gem (Groot 2001), and IP Peg (Harlaftis et al. 1999) through similar analyses. Therefore the emission line of He II 4686 Å can be a good tracer of a spiral structure in an accretion disk (e.g., Han et al. 2020). However, the emission mechanism of these high excitation lines is still controversial. Since WZ Sge-type DNe are a low mass-transfer rate system, these high excitation lines are not likely associated with a hot spot. Morales-Rueda and Marsh (2002) suggested two scenarios for the formation of He II 4686 Å; either a spiral structure itself, or an irradiated temperature-inversion layer on the spiral structure. Observational results from WZ Sge and GW Lib favored the irradiation scenario based on the line profile evolution (Nogami & Iijima 2004; Hiroi et al. 2009). In general, these high-excitation lines are present only in the early stage of superoutbursts. On the other hand, a sodium doublet (Na D, λ5890/5896 Å) is observed even during the post-superoutburst stage as absorption (EG Cnc; Patterson et al. 1998) or emission (WZ Sge; Nogami & Iijima 2004, GW Lib; van Spaandonk et al. 2010, SSS J122221.7−31152; Neustroev et al. 2017, V3101 Cyg; Tampo et al. 2020). These authors have discussed the possible association of the Na D line with the mass reservoir, which can be a mass supplier during a rebrightening phase (Kato et al. 1998; Hellier 2001). Nogami and Iijima (2004) discussed that the origins of Na D line at the optical peak and in the post-superoutburst stage are likely different.

In this paper, section 2 describes an overview of observations. Section 3 presents our results of spectroscopic and photometric observations. We discuss the characteristics of our spectra, light curve profiles, and correlation between the observational features and system parameters in section 4. We give our summary in section 5.

2 Observations and analysis

In this paper, we present the observations of 17 DN outbursts. The low-resolution spectroscopic observations in this paper were carried out using the Kyoto Okayama Optical Low-dispersion Spectrograph with an Integral Field Unit (KOOLS-IFU; Matsubayashi et al. 2019) mounted on the 3.8 m telescope Seimei at the Okayama Observatory, Kyoto University (Kurita et al. 2020). The log of our spectroscopic observations is listed in table 1. The wavelength coverage of VPH-Blue of KOOLS-IFU is

Table 1. Log of spectroscopic observations.

Name	DNe type*	P_{orb} (d)	BJD observed	Days since peak (d)	Peak – quiescence magnitude mag (filter)
AL Com	UGWZ	0.056668	2458591.2	2.5	12.9(*CV*) – 19.8(*V*)
			2458592.1	3.4	
			2458594.2	5.5	
EQ Lyn	UGWZ	0.0528(1)	2458757.3	3.3	10.3(*CV*) – 19.1(*g*)
MASTER OT J234843.23+250250.4	UGSU	0.032†	2458793.2	4.5	14.4(*CR*) – 20.3(*r*)
NN Cam	UGSU	0.07391(2)	2458826.1	8.9	12.6(*CV*) – 18.5(*V*)
TCP J00590972+3438357	UGWZ	0.0543(1)	2458831.1	0.2	12.5(*CV*) – 21.0(*g*)
ASASSN-19ado	UGWZ	0.06318(5)	2458842.0	2.3	12.8(*g*) – 23:(*g*)
ASASSN-19ady	UGSU:	—	2458845.1	1.3	14.7(*g*) – 21.5(*r*)
TCP J06073081−0101501	UGWZ	0.062(1)	2458877.1	0.5	13.9(*CV*) – >22
DDE35	UGSU	0.132(2)†	2458929.2	—	15.2(*CV*) – 19.3(*G*)
			2458930.1	—	
MASTER OT J061642.05+435617.9	UGWZ	0.0549(1)	2458929.1	1.7	15.0(*CR*) – >23
ZTF20aavnpug	UGWZ:	—	2458968.2	6.2	15.3(*G*) – >23
PQ And	UGWZ	0.0559(2)	2459003.3	>4.1	10.0(*CV*) – 19.2(*V*)
TCP J20034647+1335125	UGWZ	0.05537(4)	2459077.2	0.2	12.6(*CR*) – 21.5(*r*)
ASASSN-20kv	UGWZ:	0.05604(2)†	2459088.2	0.4	14.1(*g*) – 23:(*g*)
ASASSN-20kw	UGSU:	—	2459089.3	0.2	14.7(*g*) – 23:(*g*)
MASTER OT J213908.79+161240.2	UGWZ:	0.0584(1)	2459119.2	0.6	15.5(*CR*) – >23
ASASSN-20mf	UGSU:	—	2459119.2	4.3	14.5(*g*) – >23

*UGWZ: WZ Sge-type, UGSU: SU UMa-type, ":" means a candidate of that type.
†The superhump period is listed instead of P_{orb}.

Table 2. Equivalent width (EW) and full width at half maximum (FWHM) of our spectra.

Name	BJD	Hα		Hβ		Hγ	
	observed	EW*	FWHM (Å)	EW*	FWHM (Å)	EW*	FWHM (Å)
AL Com	2458591.2	—	—	− 7.3(2)	62.5(9)	—	—
	2458592.1	—	—	− 3.7(1)	35.3(8)	—	—
	2458594.2	—	—	− 4.4(2)	81.67(9)	—	—
EQ Lyn	2458757.3	− 6.6(6)	24.1(6)	− 4.70(8)	28.0(7)	− 4.6(1)	20.5(5)
	2458757.3	1.3(2)	17.2(5)	—	—	—	—
MASTER J2348	2458793.2	—	—	7.8(1)	47.6(8)	—	—
NN Cam	2458826.1	− 7.7(1)	20.6(4)	− 12.4(2)	31.1(4)	− 9.7(1)	19.5(2)
TCP J0059	2458831.1	− 2.7(1)	29.3(9)	− 3.26(9)	22.7(8)	− 1.81(7)	15.2(5)
ASASSN-19ado	2458842.0	—	—	− 3.5(2)	31.1(6)	− 2.7(1)	28.3(5)
	2458842.0	20.51(7)	11.80(4)	1.58(6)	10.6(3)	0.57(4)	8.1(5)
ASASSN-19ady	2458845.1	—	—	− 3.4(1)	18.4(5)	-4.64(7)	19.7(8)
TCP J0607	2458877.1	2.52(6)	9.1(3)	− 2.9(1)	38.7(9)	2.01(8)	25.4(8)
DDE35	2458929.2	46.1(2)	24.13(6)	26.2(1)	21.82(9)	20.8(1)	22.9(2)
	2458930.1	39.1(1)	25.29(8)	17.2(1)	20.4(1)	44.3(1)	37.9(1)
MASTER J0616	2458929.1	—	—	− 3.2(1)	31.0(9)	—	—
ZTF20aavnpug	2458968.2	22.05(7)	14.12(5)	—	—	—	—
PQ And	2459003.3	5.67(7)	12.2(1)	− 3.8(1)	36.1(9)	− 6.2(1)	32.6(7)
TCP J2003	2459077.2	− 3.33(9)	28.7(8)	− 3.33(7)	21.6(9)	− 3.6(1)	21.3(9)
ASASSN-20kv	2459088.2	—	—	− 3.25(7)	16.7(5)	—	—
ASASSN-20kw	2459089.3	− 2.92(7)	16.6(4)	− 6.8(1)	28.7(5)	− 14.3(1)	33.5(2)
MASTER J2139	2459119.2	17.68(8)	13.67(6)	1.54(6)	6.3(3)	—	—
ASASSN-20mf	2459119.2	7.69(3)	8.69(3)	—	—	—	—

*A negative EW for an emission line.

4200–8000 Å, and its wavelength resolution is $R = \lambda/\Delta\lambda \sim 400$–600. The data reduction was performed using IRAF in the standard manner (bias subtraction, flat-fielding, aperture determination, spectral extraction, wavelength calibration with arc lamps, and normalization by the continuum). All the observation epochs are described in Barycentric Julian Date (BJD).

Our time-resolved CCD photometric observations were made with the Variable Star Network collaborations (VSNET; Kato et al. 2004). The logs of photometric observations are listed in tables E2–E18.[1] The zero-points of all the VSNET data were adjusted to the data of the *V*- or *CV*-band observations for each object. We also use the photometric data from All-Sky Automated Survey for Supernovae (ASAS-SN) Sky Patrol (Shappee et al. 2014; Kochanek et al. 2017), the Zwicky Transient Facility (ZTF; Bellm et al. 2019) Public Data Release 4, the ZTF alert broker Lasair (Smith et al. 2019), and Gaia Photometric Science Alerts (Wyrzykowski et al. 2012) to examine the global light-curve profiles, especially on the type of rebrightenings and on the outburst cycles. The phase dispersion minimization (PDM) method was used for period analysis (Stellingwerf 1978). The 90% confidence range of θ statistics by the PDM method was determined following Fernie (1989) and Kato et al. (2010). Before period analysis, the global trend of the light curve was removed by subtracting a smoothed light curve obtained by locally weighted polynomial regression (LOWESS; Cleveland 1979).

[1]Tables E1–E26 are available in the supplementary data section of this article online.

3 Results

We show the spectra and light curves of our 17 sources in figures 1, 2, 3, 4, and 5. In table 2, the full width at half maximum (FWHM) and equivalent width (EW) of Balmer lines of our spectra are listed. In the light curves of figures 1–5, the quiescence magnitude or upper limit is presented as a dashed line; the epoch when the spectroscopic observation was performed is also shown, with a solid line. As seen in the light curves of figures 1–5, all our spectra were taken during their superoutbursts. Our spectra for six objects were obtained less than 1 d from the optical peak of their superoutbursts. Among our 17 sources, 11 objects are WZ Sge-type DNe and their candidates, based on the presence of early superhumps or global light-curve profiles including rebrightenings. The other six objects are SU UMa-type DNe and candidates.

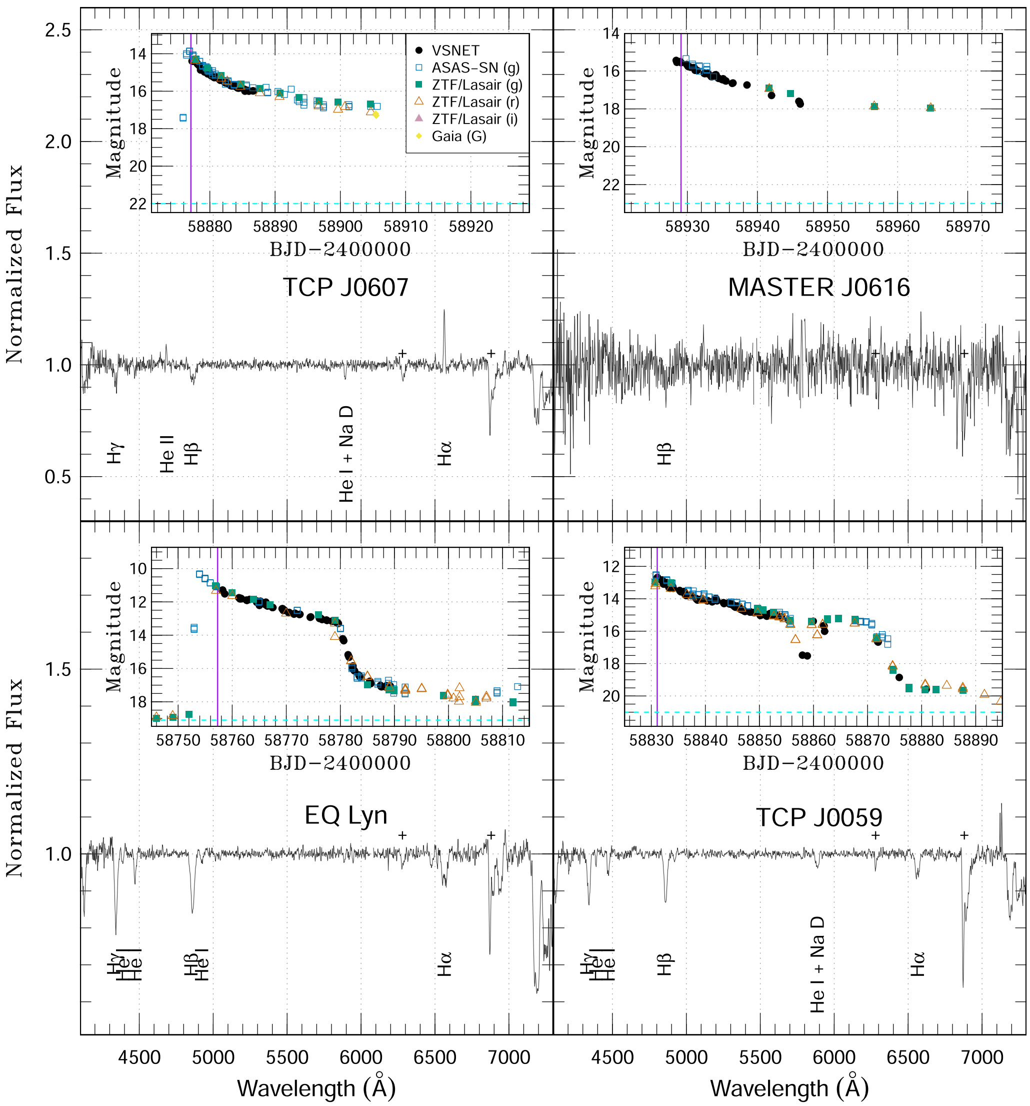

Fig. 1. Normalized spectra and light curves during the outburst of TCP J0607 (upper left), MASTER J0616 (upper right), EQ Lyn (lower left), and TCP J0059 (lower right). The "+" signs in the spectra represent telluric absorptions. The solid line in the light curve figures represents the date of spectroscopic observations, and the dashed line shows the quiescence or upper limit magnitude. Filled circles are data from VSNET (Kato et al. 2004), filled squares, open triangles and filled triangles are from ZTF (Bellm et al. 2019) or Lasair (Smith et al. 2019) in the *g*, *r*, and *i* bands, open squares are from ASAS-SN (Shappee et al. 2014) in the *g* band, and filled diamonds are from Gaia alert (Wyrzykowski et al. 2012) in the *G* band, respectively. (Color online)

3.1 AL Com

AL Com is one of the well-studied WZ Sge-type DNe, with an orbital period of 0.056668 d (Kato et al. 2009). Its WZ Sge-type nature was first reported by Kato et al. (1996), and recent superoutbursts were observed in 2001 May (Ishioka et al. 2002), 2007 October (Uemura et al. 2008), 2013 December (Kato et al. 2014), and 2015 March (Kimura et al. 2016), establishing the superoutburst cycle to be 6–7 yr. The 2015 superoutburst was less energetic than other superoutbursts; its outburst amplitude was smaller than the other superoutbursts of AL Com and early superhumps were not observed. These points suggest that the disk radius did not reach the 2:1 resonance radius of the system during the 2015 superoutburst (Kimura et al. 2016).

The 2019 outburst was firstly reported by M. Moriyama on BJD 2458588.2 (vsnet alert 23171).[2] This is only four years after the last superoutburst in 2015. The subsequent photometric observations detected early superhumps, confirming that the 2019 outburst is a WZ Sge-type superoutburst (figure 6). The period of early superhumps is 0.0565(1) d (figure 6), which is consistent with Kato et al. (1996), Ishioka et al. (2002), and Kato et al. (2014). Thus

[2] ⟨http://ooruri.kusastro.kyoto-u.ac.jp/mailarchive/vsnet-alert/23171⟩.

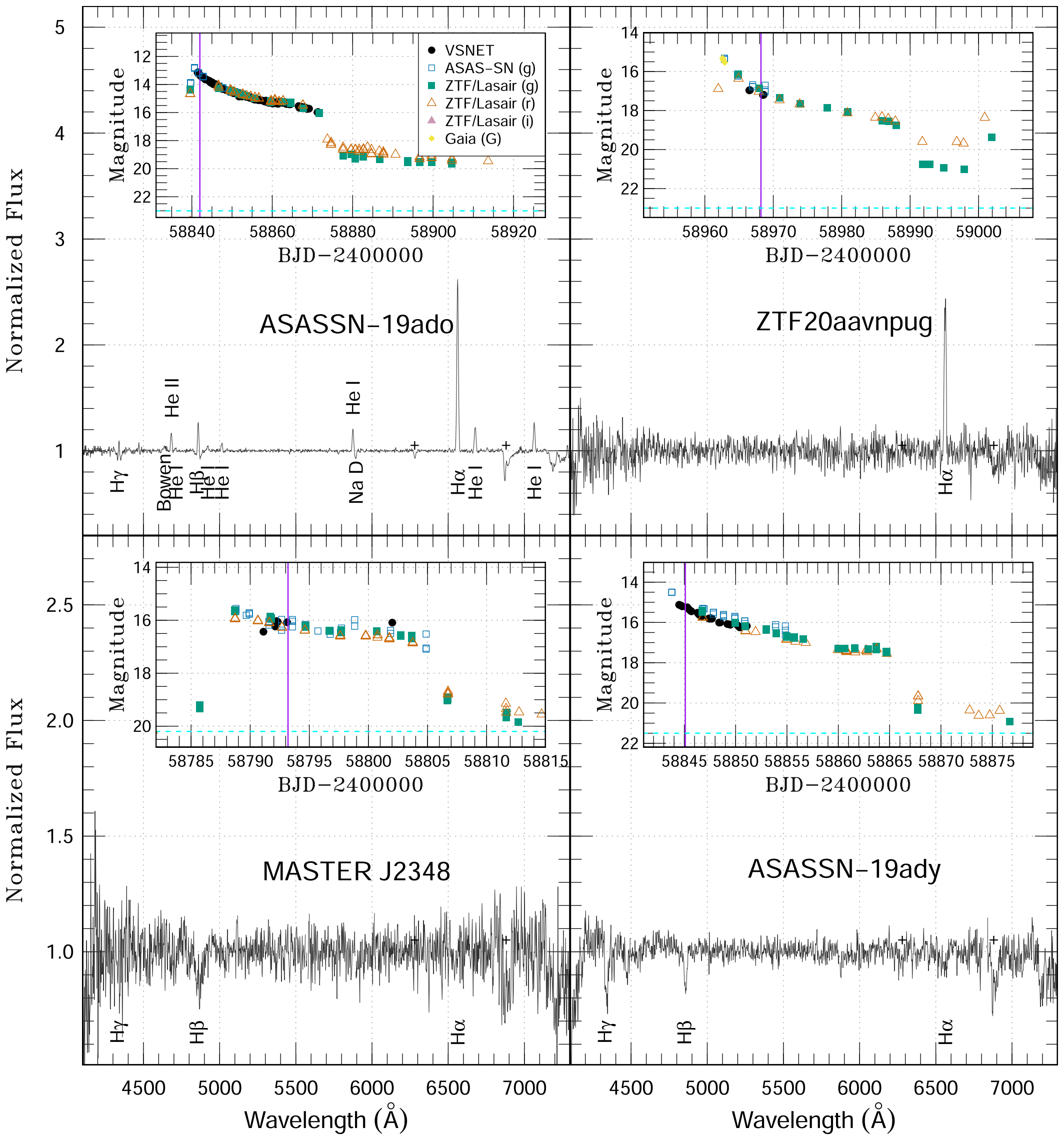

Fig. 2. Same as figure 1 but for ASASSN-19ado (upper left), ZTF202aavnpug (upper right), MASTER J2348 (lower left), and ASASSN-19ady (lower right). (Color online)

the 2015 superoutburst had no impact on the 6–7 yr superoutburst cycle of AL Com. The $O - C$ diagram of the superhump period and the evolution of the superhump amplitude during the 2019 superoutburst are shown in figure 7. The spectroscopic observations were performed on BJD 2458591.2, 2458592.1, and 2458594.2. Even though their signal-to-noise ratios are low, an Hβ absorption line is present in all the three spectra (lower left-hand panel of figure 3). In our spectra, Hα was not detected, neither as emission nor absorption. Augusteijn et al. (1995) observed the 1995 superoutburst of AL Com 5 d after the outburst peak. They reported the shallow and wide absorption lines of Balmer series and He I 4471 Å, which is likely consistent with our spectra. The spectra during quiescence were studied by Howell et al. (1998) and Szkody et al. (1998, 2003), in which AL Com showed the emission lines of the Balmer series.

3.2 EQ Lyn

EQ Lyn (= SDSS J074531.92+453829.6; Szkody et al. 2006) is a known WZ Sge-type DN with an orbital period of 0.0528(1) d (Gänsicke et al. 2009). Its previous outburst in 2006 was recorded in the Catalina Real-Time Transient Survey (Drake et al. 2009). The 2019 superoutburst was firstly reported by T. Kojima on BJD 2458756.3 (vsnet alert 23591).[3] According to the ASAS-SN Sky Patrol data (Shappee et al. 2014), EQ Lyn was in the superoutburst

[3] ⟨http://ooruri.kusastro.kyoto-u.ac.jp/mailarchive/vsnet-alert/23591⟩.

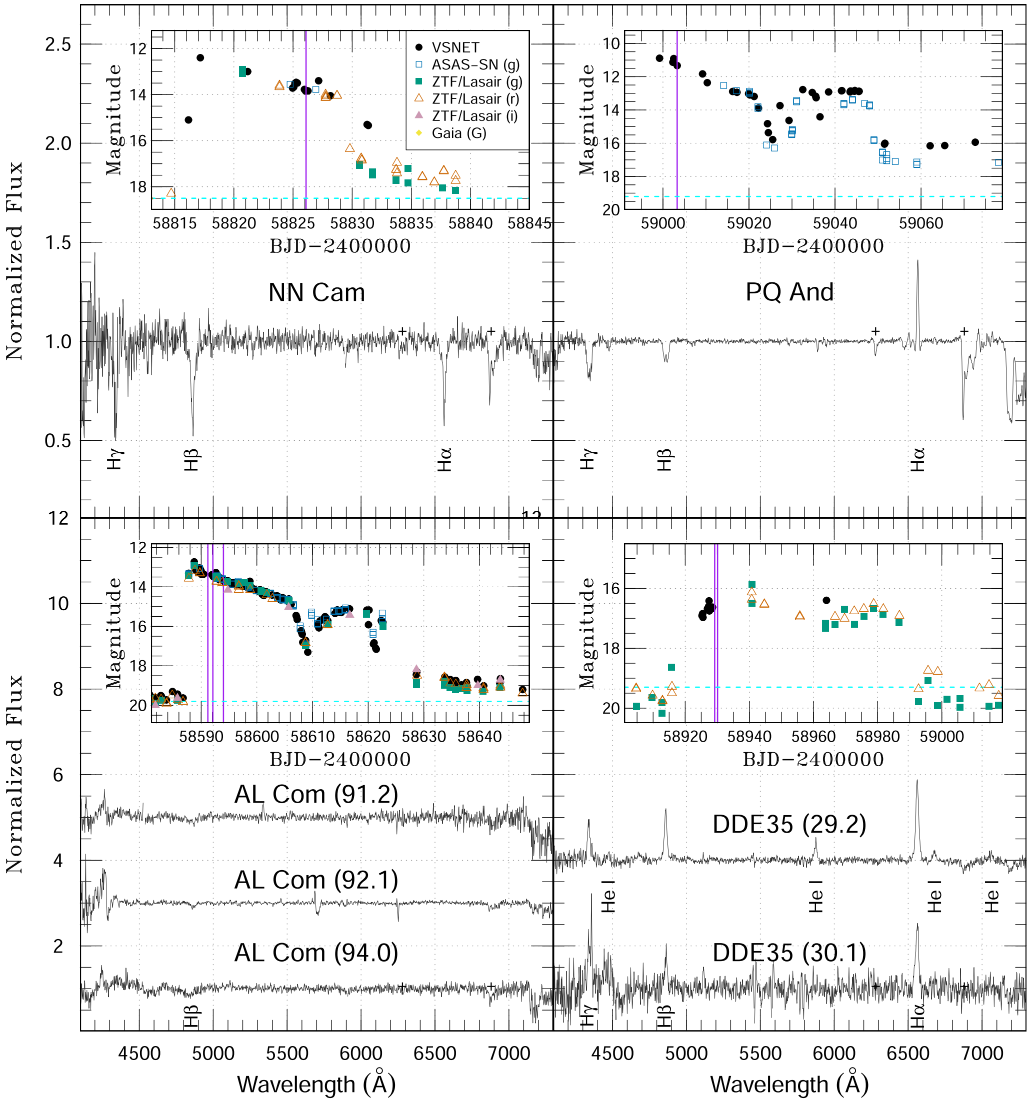

Fig. 3. Same as figure 1 but for NN Cam (upper left), PQ And (upper right), AL Com (lower left), and DDE35 (lower right). (Color online)

since BJD 2458753.0. Our spectroscopic observation was performed on BJD 2458757.3, which is 3.3 d after the optical peak (Isogai et al. 2019a). Its spectra and light curve during the 2019 superoutburst are presented in the lower left-hand panel of figure 1. The absorption lines of Balmer, He I 4388, 4471, and 4922 Å are seen in the spectra, and a weak emission component is superposed in Hα. Early superhumps are detected in our photometric observations with a period of 0.0525(1) d (figure 6). No rebrightening was observed, hence EQ Lyn is a type-D object among WZ Sge-type DNe (Imada et al. 2006; Kato 2015). The $O - C$ diagram of the superhump period and the evolution of the superhump amplitude during the 2019 superoutburst are shown in figure 8. The superhump period during Stage B was obtained as 0.054753(3) d. The quiescence spectra from Szkody et al. (2006) show strong Balmer emission lines from the accretion disk and broader absorption lines from the primary WD. Compared to its quiescence spectra, all Balmer lines in our spectra are turned into absorption, which is consistent with a spectrum of a DN outburst.

3.3 MASTER OT J234843.23+250250.4

MASTER OT J234843.23+250250.4 (hereafter MASTER J2348) was firstly discovered in 2013 by Shurpakov et al. (2013). Photometric observations during the 2013 outburst confirmed that MASTER J2348 is a SU UMa-type DN with a superhump period of 0.032 d, which is below the period minimum (Kato et al. 2014). Kato et al. (2014) suggested that this object should be a hydrogen-poor EI Psc-type DNe

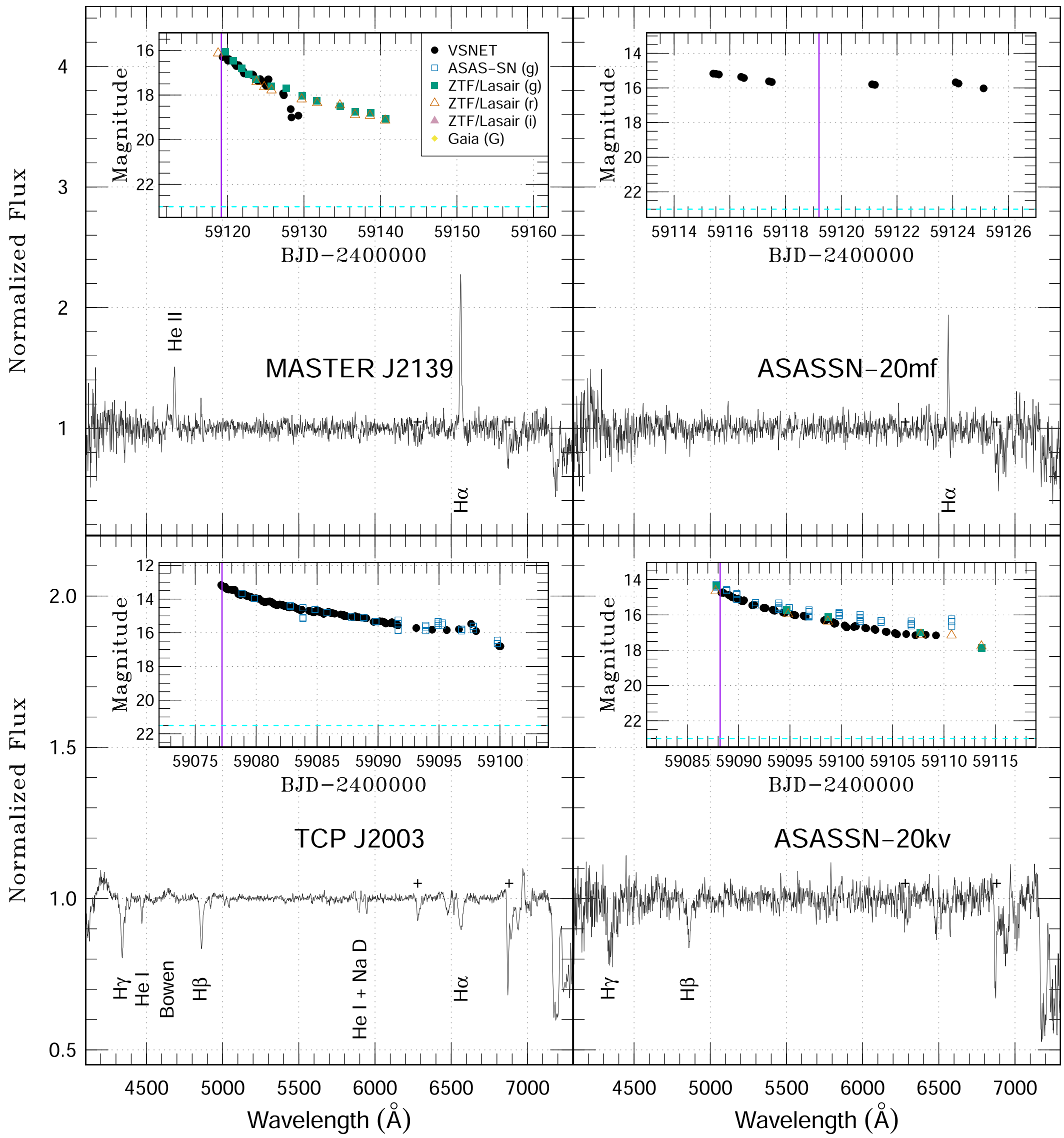

Fig. 4. Same as figure 1 but for MASTER J2139 (upper left), ASASSN-20mf (upper right), TCP J2003 (lower left), and ASASSN-20kv (lower right). (Color online)

based on this superhump period, as yydrogen-deficient AM CVn-type DNe with this P_{orb} do not show outbursts (Ramsay et al. 2012).

Our spectroscopic observation was performed on BJD 2458793.2 during its 2019 superoutburst, and our result is presented in the lower left-hand panel of figure 2. This observation revealed a weak Hβ absorption line, although no strong He lines are present (Isogai et al. 2019b). These features support that MASTER J2348 is an EI Psc-type DN rather than an AM CVn-type DN, as proposed by Kato et al. (2014).

3.4 NN Cam

NN Cam is a known SU UMa-type DN with an orbital period of 0.0717 d, the superhump period of 0.07391(2) d, and the mass ratio estimated as 0.11–0.17 using the empirical relation of superhumps (Patterson et al. 2005a). Its superoutbursts were studied in Khruslov (2005), Kato et al. (2009), and Shears et al. (2011). The 2019 outburst was first detected by Y. Maeda on BJD 2458816.2 and our spectroscopic observation was performed on BJD 2458826.1. Our spectra in the upper left-hand panel of figure 3 show clear Balmer absorption lines, even though the peak epoch of this outburst is around BJD 2458817.2, which is 9 d prior to our spectroscopic observation. Figure 9 shows the $O-C$ diagram during the 2019 superoutburst, using the same $C = 0.0743$ d as Kato et al. (2015). Judging from the shape of the $O-C$ diagram, our time-resolved photometric observations were likely during Stage C, which also supports that our spectroscopic observation was in the late stage of the 2019 superoutburst. These results suggest that NN Cam is

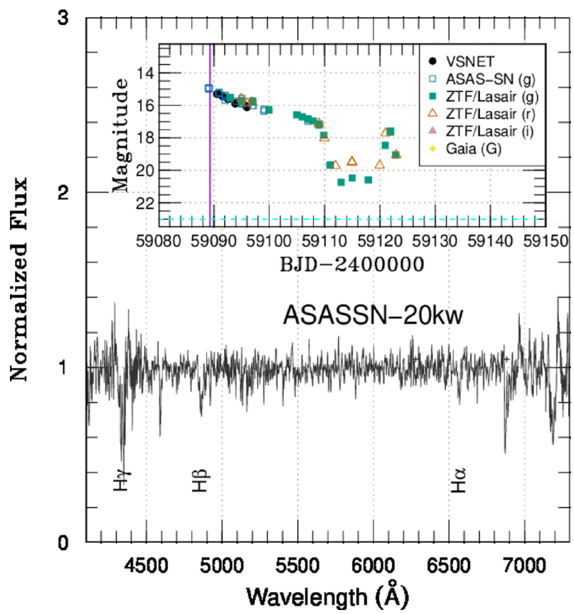

Fig. 5. Same as figure 1 but for ASASSN-20kw. (Color online)

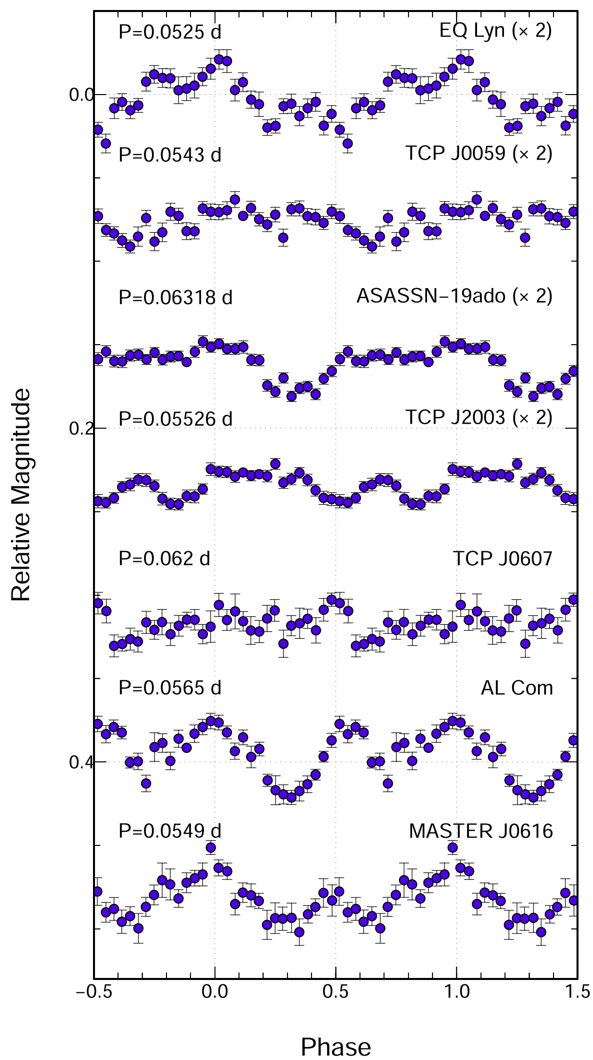

Fig. 6. Mean profiles of early superhumps of EQ Lyn, TCP J0059, ASASSN-19aod, TCP J2003, TCP J0607, AL Com, and MASTER J0616, from top to bottom. For the initial four objects, their magnitude scales are doubled for visualization. (Color online)

a nearly face-on system, where the limb-darkening effect is relatively weak.

3.5 TCP J00590972+3438357

TCP J00590972+3438357 (= ASASSN-19adh = ZTF19acyfeuy, hereafter TCP J0059) was newly discovered by S. Ueda on BJD 2458830.9 at 12.4 mag.[4] The quiescence counterpart is $G = 21.073$ mag from Gaia DR2 (Gaia Collaboration 2018), hence the outburst amplitude is ∼8.7 mag. Our spectra were taken on BJD 2458831.1, which is only 0.2 d after the discovery (Isogai et al. 2019c). The spectra show Balmer, He I 4388, 4471, and 5876 Å absorption lines, classifying this optical transient as a DN outburst (lower right-hand panel of figure 1). In Hα, a weak emission component is superposed. A possible Na D absorption line is seen as well. From our photometric observations, we detect early superhumps with the period of 0.0543(1) d (figure 6), and Stage A superhump with the period of 0.0564(1) (figure 10). These superhump periods yield that the mass ratio q of TCP J0059 is 0.103(6) using the method proposed by Kato and Osaki (2013). TCP J0059 also showed a long-duration rebrightening (type-A rebrightening: Imada et al. 2006). Although the profile of early superhumps is not clearly double-wave due to its small amplitude, the long waiting time until the ordinary superhump appearance (∼10 d), short superhump period, and rebrightening profile support that TCP J0059 is a WZ Sge-type DN.

[4] ⟨http://www.cbat.eps.harvard.edu/unconf/followups/J00590972+3438357.html⟩.

3.6 ASASSN-19ado

ASASSN-19ado (= Gaia20abm = ZTF19adbgfwx) was first detected by ASAS-SN (Shappee et al. 2014) at 13.52 mag on BJD 2458839.7 as a CV candidate, and our spectroscopic observation was carried on BJD 2458842.0 (Maehara 2019). As the quiescence counterpart is likely ∼23 mag, from the PAN-STARRS1 image (Chambers et al. 2016), the outburst amplitude is ∼9 mag. In the upper left-hand panel of figure 2, the spectra show strong emission lines of Balmer and He I 4713, 4922, 5015, 5876, 6678, and 7065 Å. Na D absorption, relatively strong He II 4686 Å emission, and Bowen blend emission lines are visible in our spectra as well. Our photometric observations detect early superhumps with the period of 0.06316(1) d (figure 6), establishing that ASASSN-19ado is a WZ Sge-type DN. No rebrightening was observed, classifying it as a type-D

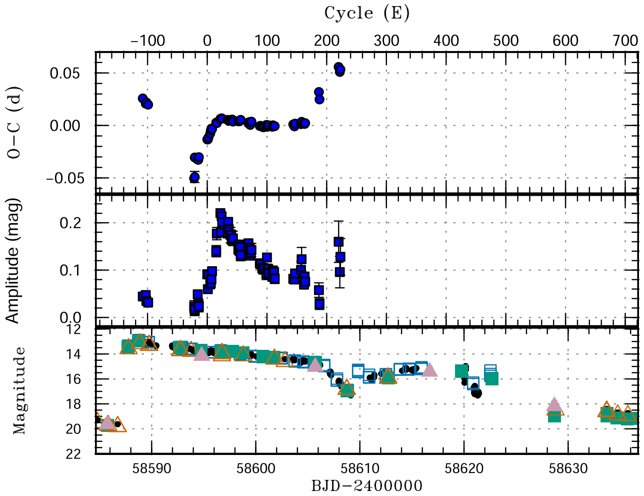

Fig. 7. Top panel: $O - C$ diagram of ALCom. Note that $C = 0.057318$ d was used to draw this panel following Kimura et al. (2016). Times of superhump maxima are available as supplementary material in table E21. Middle panel: Evolution of the superhump amplitudes of corresponding phase. Bottom panel: Light curve during the superoutburst. The symbols are the same as in figure 1. (Color online)

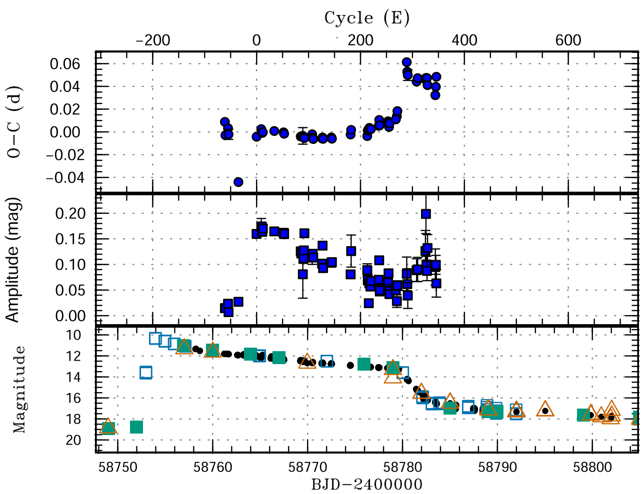

Fig. 8. Top panel: $O - C$ diagram of EQ Lyn. Note that $C = 0.0547$ d was used to draw this panel. Times of superhump maxima are available as supplementary material in table E19. Middle panel: Evolution of the superhump amplitudes of corresponding phase. Bottom panel: Light curve during the superoutburst. The symbols are the same as in figure 1. (Color online)

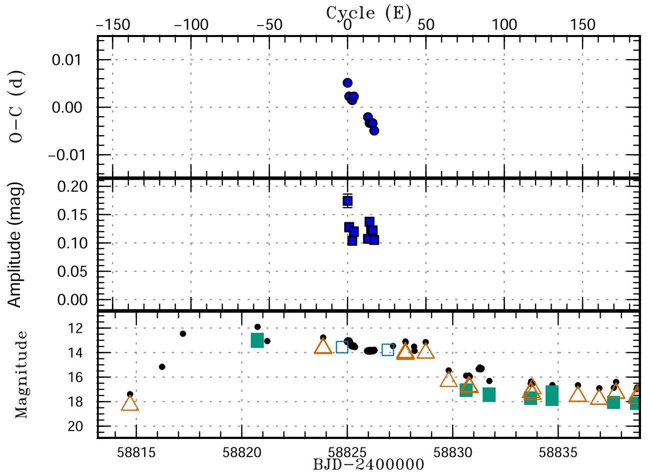

Fig. 9. Top panel: $O - C$ diagram of NN Cam. Note that $C = 0.0743$ d was used to draw this panel following Kato et al. (2015). Times of superhump maxima are available as supplementary material in table E22. Middle panel: Evolution of the superhump amplitudes of corresponding phase. Bottom panel: Light curve during the superoutburst. The symbols are the same as in figure 1. (Color online)

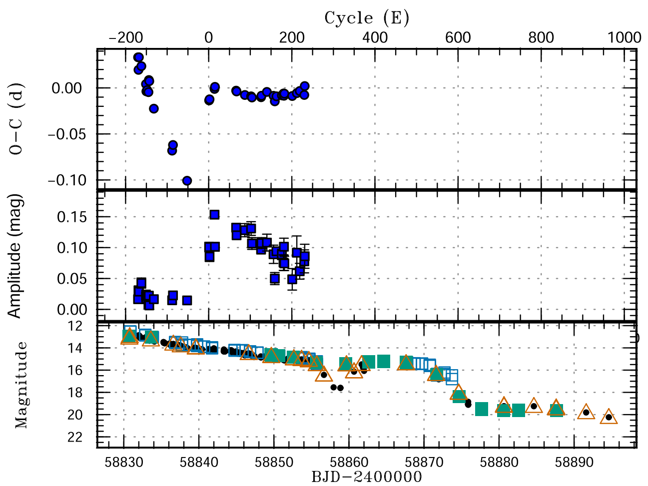

Fig. 10. Top panel: $O - C$ diagram of TCP J0059. Note that $C = 0.0554$ d was used to draw this panel. Times of superhump maxima are available as supplementary material in table E20. Middle panel: Evolution of the superhump amplitudes of corresponding phase. Bottom panel: Light curve during the superoutburst. The symbols are the same as in figure 1. (Color online)

rebrightening object (Imada et al. 2006). As the period of Stage A superhump was detected as 0.0651(1) d (figure 11), the mass ratio is estimated to be 0.081(5) following Kato and Osaki (2013).

3.7 ASASSN-19ady

ASASSN-19ady was first discovered by ASAS-S9 (Shappee et al. 2014) on BJD 2458843.8 at 14.42 mag as a CV candidate. The optical quiescence counterpart is 21.5 mag in the r band of the Pan-STARRS1 catalog (Chambers et al. 2016), therefore the outburst amplitude is ~7.1 mag. Before this 2019 outburst, no optical brightening had been recorded by ASAS-SN (Shappee et al. 2014) nor ZTF (Bellm et al. 2019) since 2013, which indicates the outburst cycle is likely longer than 6 yr. The spectroscopic observation by Seimei telescope was performed on BJD 2458845.1, which is 1.3 d from the discovery (Isogai & Maehara 2019). All Balmer lines are seen as absorption, which is consistent with the early phase spectra of a DN outburst (lower right-hand panel of figure 2). Although our photometric observations

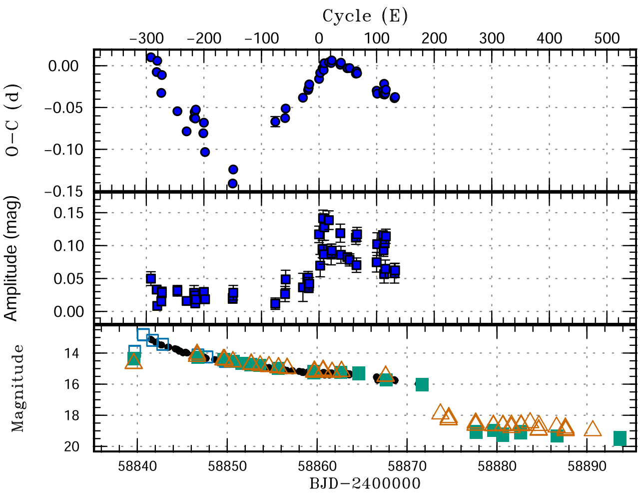

Fig. 11. Top panel: $O-C$ diagram of ASASSN-19ado. Note that $C = 0.064085$ d was used to draw this panel. Times of superhump maxima are available as supplementary material in table E23. Middle panel: Evolution of the superhump amplitudes of corresponding phase. Bottom panel: Light curve during the superoutburst. The symbols are the same as in figure 1. (Color online)

are not capable of confirming the presence of superhumps, the large amplitude and long duration of outburst, and the long outburst cycle, suggest that ASASSN-19ady is a SU UMa-type DN candidate.

3.8 TCP J06073081−0101501

TCP J06073081-0101501 (= ASASSN-20bk = Gaia20baq = ZTF20aakficj, hereafter TCP J0607) was found by the Brazilian Transient Search on BJD 2458876.6 at 13.9 mag.[5] Since the quiescence counterpart is not present in the PAN-STARRS1 (Chambers et al. 2016) image, the outburst amplitude is likely larger than 8 mag. Our spectroscopic observation was performed on BJD 2458877.1, which is 0.5 d from the discovery (Maehara 2020). Our spectra in the upper left-hand panel of figure 1 show Hα emission, and weak Hβ and Hγ absorption lines. He II 4686 Å emission and possible Na D absorption lines are present as well. The subsequent photometric observations detected early superhumps with the period of 0.062(1) d (figure 6); therefore, TCP J0607 is classified as a WZ Sge-type DN. Due to the solar conjunction, its later light curve evolution was not observed. Therefore its ordinary superhump periods and rebrightening profile are unknown.

3.9 DDE35

DDE35 is a SU UMa-type DN candidate with the superhump period of 0.1322(1) d, which is above the period gap (vsnet-alert 24821).[6] We note that this period is obtained using observations for only two nights and can be a spurious detection. The spectra were obtained on BJD 2458929.2 and 2458930.1 (lower right-hand panel of figure 3). Both of our spectra show strong Balmer emission lines. In the spectra on BJD 2458929.2, He I 4471, 5876, 6678, and 7065 Å are present as emission lines, which are less prominent on BJD 2458929.2 due to lower signal-to-noise ratio. The spectra during the 2016 outburst reported by Fraser et al. (2016) also showed narrow emission lines of Balmer series and He I 5876, 7065 Å, which is consistent with our spectra in the 2020 superoutburst. The quiescence spectra by Worpel and Schwope (2017) show a flat continuum and stronger Balmer and He I emission lines than in outburst. Note that we cannot determine the peak epoch due to the lack of photometric observations and its peculiar double-peak outburst profile. Judging from the light curve profile, our spectra were likely obtained in the first days of the outburst.

3.10 MASTER OT J061642.05+435617.9

MASTER OT J061642.05+435617.9 (= ZTF20aaukvqw, herafter MASTER J0616) was discovered by the MASTER team on BJD 2458927.4 (Shumkov et al. 2020). Shumkov et al. (2020) reported that MASTER J0616 can be a classical nova. As there is no VizieR match object,[7] the outburst amplitude is larger than 8 mag. Our spectra on BJD 2458929.1 in the upper right-hand panel of figure 1, however, show a narrow Hβ absorption line with no clear sign of other lines (Isogai 2020). These features suggest this transient is a DN outburst in the early phase rather than a nova eruption. The subsequent photometric observations showed possible early superhumps with the period of 0.0549(1) d (figure 6). Its large outburst amplitude and long waiting time until the superhump appearance also confirm that MASTER J0616 is a WZ Sge-type DN.

3.11 ZTF20aavnpug

ZTF20aavnpug (= Gaia20byj) was first detected by ZTF (Bellm et al. 2019) at 16.9 mag on BJD 2458961.5, and Gaia alert (Wyrzykowski et al. 2012) also reported it as a new transient. As there is no quiescence counterpart in the Pan-STARRS1 (Chambers et al. 2016) image, the outburst amplitude is likely larger than 7.5 mag. There is no recorded outburst in ASAS-SN (Shappee et al. 2014), ZTF (Bellm et al. 2019) or Gaia alert (Wyrzykowski et al. 2012).

[5] ⟨http://www.cbat.eps.harvard.edu/unconf/followups/J06073081-0101501.html⟩.

[6] ⟨http://ooruri.kusastro.kyoto-u.ac.jp/mailarchive/vsnet-outburst/24821⟩.

[7] ⟨http://vizier.u-strasbg.fr/viz-bin/VizieR⟩.

Our spectra on BJD 2458968.2 show a strong Hα emission line with no other clear features (upper right-hand panel of figure 2; Isogai & Maehara 2020). Although our photometric observations were not capable of confirming superhumps, its large amplitude, steeper decline followed by exponential decay in the outburst profile, and rebrightening profile suggest that ZTF20aavnpug is a WZ Sge-type DN candidate.

3.12 PQ And

PQ And was discovered by D. McAdam in 1988 as a classical nova candidate; however, later it was classified as a DN due to the lack of nebular features in the spectrum (Wade & Hamilton 1988). Moreover, Richter (1990) established its outburst cycle as ∼25 yr from the archive data. Patterson et al. (2005b) found that its $P_{\rm orb}$ is ∼0.0559(2) d. These features established that PQ And is a WZ Sge-type DN.

Its outburst in 2020 was first reported by K. Hirosawa on BJD 2458998.2 (vsnet-alert 24301),[8] and our spectroscopic observation was carried out on BJD 2459003.3. This was the first outburst observed since the initial discovery and outburst in 1988. This 2020 superoutburst was followed by a single rebrightening plus a long-duration rebrightening with a 2 mag dip during the rebrightening. Such a dip during the long-duration rebrightening was observed in AL Com (subsection 3.1, Kimura et al. 2016), ASASSN-15po (Namekata et al. 2017), V803 Cen (vsnet alert 19627),[9] and MASTER OT J172758.09+380021.5 (vsnet alert 23720).[10] Therefore, a small dip might be a common feature in long-duration rebrightenings. We note that, since the 2020 superoutburst was discovered just after the solar conjunction, the peak of the superoutburst is likely before the discovery date. Our spectra in the upper right-hand panel of figure 3 show Balmer absorption lines and superposed emission lines in Hα and Hβ (Isogai et al. 2020a). Compared to the quiescence spectra reported in Schwarz et al. (2004) and Han et al. (2020), absorption components of Balmer lines in our spectra are much stronger, which is consistent with the spectra during a DN outburst. According to McAdam et al. (1988), the spectra during the 1988 outburst showed a strong O III emission line, however our spectra in the 2020 outburst do not show any feature of O III. We suspect that, as PQ And was first thought to be a classical nova, they might mistake noise or cosmic rays for the O III emission line. We note that, as our spectra were taken in astronomical twilight and the elevation of the object was 19°, our spectra are strongly contaminated by telluric absorption and sunlight.

[8] ⟨http://ooruri.kusastro.kyoto-u.ac.jp/mailarchive/vsnet-alert/24301⟩.

[9] ⟨http://ooruri.kusastro.kyoto-u.ac.jp/mailarchive/vsnet-alert/19627⟩.

[10] ⟨http://ooruri.kusastro.kyoto-u.ac.jp/mailarchive/vsnet-alert/23720⟩.

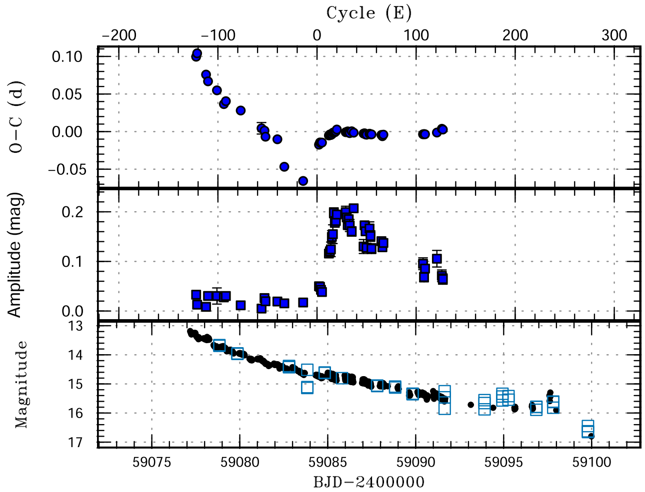

Fig. 12. Top panel: $O-C$ diagram of TCP J2003. Note that $C = 0.0565$ d was used to draw this panel. Times of superhump maxima are available as supplementary material in table E24. Middle panel: Evolution of the superhump amplitudes of corresponding phase. Bottom panel: Light curve during the superoutburst. The symbols are the same as in figure 1. (Color online)

3.13 TCP J20034647+1335125

TCP J20034647+1335125 (= ASASSN-20kc, hereafter TCP J2003) was discovered on BJD 2459077.0 by H. Nishimura at 12.6 mag, which was not visible on one day prior.[11] The quiescence counterpart is 21.5 mag in the *r* band from Pan-STARRS1 (Chambers et al. 2016), therefore the outburst amplitude of TCP J2003 is ∼8.9 mag. Our spectroscopic observation was performed on BJD 2459077.2, which is only 0.2 d from the discovery (Taguchi et al. 2020a). Our spectra are shown in the lower left-hand panel of figure 4, which show Balmer and He I 4471 and 5876 Å absorption lines. Possible Na D absorption and Bowen Blend emission lines are detected in our spectra as well. These features confirmed TCP J2003 as a DN outburst. Our photometric follow-up observations detected early superhumps with a period of 0.05526(4) d (figure 6), and a Stage A superhump with a period of 0.05750(4) d (figure 12), yielding the mass ratio of TCP J2003 as 0.109(5) (Kato & Osaki 2013). Therefore, TCP J2003 is classified as a WZ Sge-type DN, though the rebrightening profile is unknown.

3.14 ASASSN-20kv

ASASSN-20kv (= Gaia20eeh = ZTF20abwvhwm) was discovered on BJD 2459087.8 at 14.1 mag in the *g* band and

[11] ⟨http://www.cbat.eps.harvard.edu/unconf/followups/J20034647+1335125.html⟩.

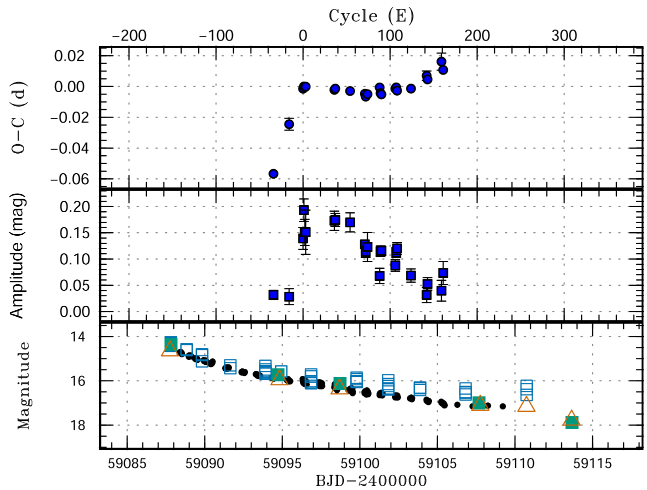

Fig. 13. Top panel: $O-C$ diagram of ASASSN-20kv. Note that $C = 0.0560$ d was used to draw this panel. Times of superhump maxima are available as supplementary material in table E25. Middle panel: Evolution of the superhump amplitudes of corresponding phase. Bottom panel: Light curve during the superoutburst. The symbols are the same as in figure 1. (Color online)

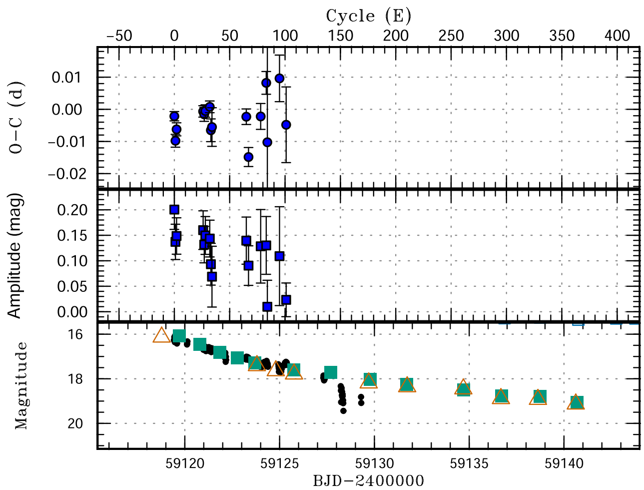

Fig. 14. Top panel: $O-C$ diagram of MASTER J2139. Note that $C = 0.0584$ d was used to draw this panel. Times of superhump maxima are available as supplementary material in table E26. Middle panel: Evolution of the superhump amplitudes of corresponding phase. Bottom panel: Light curve of MASTER J2139 during the superoutburst. (Color online)

reported as a possible classical nova in our Galaxy by ASAS-SN (Shappee et al. 2014). The quiescent counterpart is likely a blue faint object on the Pan-STARRS1 image (Chambers et al. 2016), thus the outburst amplitude is ~9 mag. We observed ASASSN-20kv with the Seimei telescope on BJD 2459088.2, which is 0.4 d from the initial detection by ASAS-SN. The spectra in the lower right-hand panel of figure 4, however, show weak Hα and Hβ absorption, revealing that ASASSN-20kv is a DN outburst rather than a classical nova eruption (Taguchi et al. 2020b). Our photometric observations detected the superhumps with a period of 0.05604(2) d during Stage B (figure 13). The long waiting time until the superhump appearance (~7 d), its short superhump period, and large superoutburst amplitude suggest that ASASSN-20kv is a WZ Sge-type DN. We note that its rebrightening profile is unknown.

3.15 ASASSN-20kw

ASASSN-20kw (= Gaia20edl = ZTF20abxxzmk) was reported by ASAS-SN (Shappee et al. 2014) on BJD 2459089.1 at 14.7 mag in the *g* band as a candidate of a galactic classical nova. As the quiescent counterpart is likely a blue faint object on the Pan-STARRS1 image (Chambers et al. 2016), the outburst amplitude is larger than 8 mag. In our spectra on BJD 2459089.3, weak Hβ and possible other Balmer absorption lines are detected (figure 5). We thus classified ASASSN-20kw as a DN outburst, not as an eruption from a classical nova (Taguchi et al. 2020c). Our photometric observations were not capable of detecting solid superhumps. As ASASSN-20kw showed a single rebrightening and its outburst amplitude is larger than 8 mag, ASASSN-20kw should be an SU UMa-type DN, and could even be a WZ Sge-type DN.

3.16 MASTER OT J213908.79+161240.2

MASTER OT J213908.79+161240.2 (= ZTF20acerdbr, hereafter MASTER J2139) was first detected by the MASTER-OAFA auto-detection system (Gorbovskoy et al. 2013) on BJD 2459118.5 at 16.1 mag (Pogrosheva et al. 2020). As no quiescent counterpart is present on the Pan-STARRS1 image (Chambers et al. 2016), the outburst amplitude is larger than 7 mag. In the upper left-hand panel of figure 4, our spectra on BJD 2459119.2 show strong emission lines of Hα and He II 4686 Å (Isogai et al. 2020b). Such a strong emission line of He II 4686 Å was observed in V455 And as well (Nogami et al. 2009; Y. Tampo et al. in preparation). Our photometric observations detected a variation with a period of 0.0584(1) d and with an amplitude of ~0.15 mag after one day from the discovery, although it is not clear whether this was double-peaked or not due to the low signal-to-noise ratio. The $O-C$ diagram of the superoutburst is presented in figure 14. The stable period and decreasing amplitude of superhumps are common in early superhumps. Since V455 And also showed large-amplitude early superhumps with amplitudes of ~0.2 mag (Katysheva & Shugarov 2009), the detected variations of MASTER J2139 can be early superhumps as well. Considering its short superhump period and large outburst amplitude, MASTER J2139 would be a good candidate for a WZ Sge-type DN.

3.17 ASASSN-20mf

ASAS-SN (Shappee et al. 2014) detected ASASSN-20mf on BJD 2459114.9 at 14.5 mag in the g band as a bright CV candidate. No quiescent counterpart is present on the Pan-STARRS1 image (Chambers et al. 2016), which indicates that the outburst amplitude is larger than 8 mag. We observed this object on BJD 2459119.2 with the Seimei telescope, and our spectra in the upper right-hand panel of figure 4 show a strong Hα emission line (Isogai et al. 2020b). Unfortunately, as ASAS-SN data was contaminated by a nearby star and there were no data in ZTF and Lasair, the global light-curve profile is unknown. Our photometric observations show a possible superhump, however they are not enough to establish its period and amplitude. As the outburst amplitude is larger than 8 mag and no past outburst is recorded in ASAS-SN nor ZTF, ASASSN-20mf is likely a SU UMa-type DN.

4 Discussion

4.1 Spectroscopic observation in the early phase of dwarf nova outbursts

We report the spectra of 17 DN superoutbursts obtained by KOOLS IFU mounted on the Seimei telescope. It is worth noting that as the outbursts from 11 objects (TCP J0059, ASASSN-19ado, TCP J0607, ZTF20aavnpug, ASASSN-19ady, MASTER J0616, TCP J2003, ASASSN-20kv, ASASSN-20kw, ASASSN-20mf, and MASTER J2139) are first detected in observed history, our quick spectroscopic observations enabled the early classification of transient types and the conducting of follow-up observations. The spectroscopic observations for 13 sources were performed less than 5 d from the outburst maxima. The spectra of TCP J0059, TCP J0607, TCP J2003, ASASSN-20kv, ASASSN-20kw, and MASTER J2139 were taken less than 1 d from the outburst peaks and discovery reports. These results demonstrate that the Seimei telescope has the capability to conduct quick follow-up observations of unknown transients.

4.2 Photometric classification of our objects

Among our objects, we newly confirmed TCP J0059, ASASSN-19ado, TCP J0607, MASTER J0616, and TCP J2003 as WZ Sge-type DNe based on the detection of early superhumps. Even though early superhumps were not confirmed for ZTF20aavnpug, ASASSN-20kv and MASTER J2139, they are good candidates of WZ Sge-type DNe based on the global light-curve profile and short-period superhumps. ASASSN-19ady, ASASSN-20kw, and ASASSN-20mf are candidates of SU UMa-type DNe because of their large outburst amplitudes and light curve profiles. Following the method given by Kato and Osaki (2013), we estimated the mass ratio of TCP J0059 as 0.103(6), that of ASASSN-19ado as 0.081(5) and that of TCP J2003 as 0.109(5). Their orbital periods, estimated mass ratios and rebrightening profiles are consistent with the distribution on the evolutionary path of CVs and WZ Sge-type DNe (Kato 2015).

4.3 Correlations between photometric and spectroscopic features

High excitation lines such as He II and the Bowen blend are often observed among WZ Sge-type DNe during their early superhump phase [e.g., WZ Sge (Baba et al. 2002; Steeghs 2001; Nogami & Iijima 2004), V592 Her (Mennickent et al. 2002), CSS 080304:090240+052501 (Djorgovski et al. 2008), OT J111217.4−353829 (vsnet-alert 9782;[12] Kato et al. 2009), V572 And (Quimby et al. 2005; Imada et al. 2007), V1838 Aql (vsnet-alert 15779;[13] Kato et al. 2014), ASASN-14cl (Teyssier 2014), PNV J17292916+0054043 (vsnet-alert 17327;[14] Kato et al. 2015), V455 And (Nogami et al. 2009; Y. Tampo et al. in preparation), and GW Lib (Hiroi et al. 2009)], though are also seen in some phase in SS Cyg (Clarke et al. 1984; Hessman et al. 1984) or high-inclination SU UMa-type DNe (Vogt 1982; Honey et al. 1988; Wu et al. 2001). Among our 17 sources, high excitation lines, including He II 4686 Å and the Bowen blend, are detected in ASASSN-19ado (He II and Bowen blend), TCP J0607 (He II), TCP J2003 (Bowen blend), and MASTER J2139 (He II). The spectra of the three objects except ASASSN-19ado were taken within 1 d from the superoutburst peaks. All these objects are WZ Sge-type DNe or candidates, supporting that high excitation lines tend to be seen in WZ Sge-type DNe.

Na D absorption or emission lines can be detected in the post-superoutburst stage of WZ Sge-type DNe, and a possible correlation between the Na D line and mass reservoir have been discussed in Patterson et al. (1998), van Spaandonk et al. (2010), Neustroev et al. (2017), and Tampo et al. (2020). However, it is not clear whether this correlation can be applied to the Na D line around the outburst peak. Even though KOOLS-IFU cannot fully separate He I 5876 Å and Na D, their asymmetry shapes imply

[12] ⟨http://ooruri.kusastro.kyoto-u.ac.jp/mailarchive/vsnet-alert/9782⟩.
[13] ⟨http://ooruri.kusastro.kyoto-u.ac.jp/mailarchive/vsnet-alert/15779⟩.
[14] ⟨http://ooruri.kusastro.kyoto-u.ac.jp/mailarchive/vsnet-alert/17327⟩.

that the Na D absorption line is visible in TCP J0059, TCP J0607, ASASSN-19ado, and TCP J2003. Among these objects, TCP J0059 showed a long-duration rebrightening (type A: Imada et al. 2006). On the other hand, ASASSN-19ado did not show any rebrightening (type D). We cannot judge the presence of rebrightenings in TCP J0607 or TCP J2003 since their post-superoutburst stages were not observed sufficiently. As the spectra of these objects in post-superoutburst stages are not obtained, we cannot examine the difference of spectra around the optical peak or in the post-superoutburst stage. Therefore, direct comparison of spectra around the optical peak and post-superoutburst stage will be vital to establish the relation between the rebrightening types and Na D features around the optical peak.

Steeghs (2001) and Baba et al. (2002) suggested that the spiral structure in the accretion disk obtained from the Doppler tomography of He II 4686 Å might associate with double-peak early superhumps. Early superhumps are believed to be an inclination-dependant variation as modeled by Osaki and Meyer (2002) and Uemura et al. (2012), and a more highly-inclined system tends to show larger-amplitude early superhumps. In our objects, He II 4686 Å was clearly observed only in ASASSN-19ado, TCP J0607, and MASTER J2139. These three objects showed large-amplitude early superhumps around the optical peaks, even though we cannot confirm that the early superhump profile of MASTER J2139 is double-peaked. In WZ Sge and V455 And, a strong He II 4686 Å emission line was detected around the optical peaks as well (Nogami & Iijima 2004; Nogami et al. 2009). These objects showed early superhumps with amplitudes larger than 0.1 mag (Kato et al. 2009). The inclinations of WZ Sge and V455 And are estimated as 75 ± 2 and 75°, respectively (Smak 1993; Araujo-Betancor et al. 2005). Both the He II 4686 Å emission line and early superhumps are observed in CSS 080304:090240+052501, OT J111217.4−353829, V572 And, ASASN-14cl, and PNV J17292916+0054043 as well. The amplitudes of early superhumps of these objects are larger than 0.15 mag (Kato 2015). We note that, as only the detections of the He II emission feature are reported on these objects, the strengths of emission are not noted in the literature. On the other hand, even though low-amplitude early superhumps are detected in EQ Lyn, TCP J0059, and TCP J2003 from our sources, their spectra did not show a detectable He II emission line. During the superoutburst of V592 Her, a very weak He II 4686 Å emission line was detected around the outburst peak (Mennickent et al. 2002), which showed early superhumps with amplitudes of 0.01 mag (Kato et al. 2010). ASASSN-20kv, which had a long waiting time until the ordinary superhump appearance, likely reflecting the early superhump stage, did not show a He II emission line either. In GW Lib, the inclination of which is $\sim 11^{\circ}$ (Thorstensen et al. 2002), even though early superhumps are not observed, a very weak He II 4686 Å emission line is visible in its spectra around the optical peak (Hiroi et al. 2009). These objects are summarized in table 3. The above discussion suggests that the strength of the He II 4686 Å emission line is likely bound to the amplitude of early superhumps, and therefore also related to the inclination of the system. This result can be understood with the occurrence of tidal instability at the 2 : 1 resonance radius, which causes a spiral structure in an accretion disk (Lin & Papaloizou 1979; Osaki & Meyer 2002). The vertical deformation of the accretion disk results in a larger early superhump amplitude in more highly inclined systems (Osaki & Meyer 2002; Uemura et al. 2012). At the same time, a He II 4686 Å line is emitted from this heated and/or irradiated spiral structure (Morales-Rueda & Marsh 2002). Because of foreshortening and limb-darkening effects, a system with higher inclination should show a stronger emission line. To determine the practical relation between early superhumps and profiles of the He II 4686 Å emission line, more objects and comprehensive observations are needed. We note that non-detections of He II emission line in MASTER J0616 and AL Com, which showed clear early superhumps, are likely due to the low signal-to-noise ratio of their spectra.

Next, we discuss the dependence of Balmer line profiles on systems using our sources that had spectra taken less than 1 d from the optical peak (TCP J0059, TCP J0607, TCP J2003, ASASSN-20kv, and MASTER J2139). Note that, though the spectra of ASASSN-20kw was taken within 0.2 d from the discovery, we excluded this object from the following discussion, as its photometric observations are relatively lacking. In the well-observed systems (e.g., Nogami & Iijima 2004; Hiroi et al. 2009), it is known that spectral profile changes over an outburst. We therefore suppose the above selection criteria for more statistical constraints. In our sources, TCP J0059, TCP J2003, and ASASSN-20kv showed all Balmer lines in absorption. This feature suggests that these three objects are mid- or low-inclined systems, which is in agreement with the observation that they showed low-amplitude early superhumps or did not show them at all. In ASASSN-14cl, Teyssier (2014) detected all Balmer series in absorption 0.5 d after the discovery. ASASSN-14cl showed early superhumps with amplitudes of 0.018 mag (Kato 2015). By contrast, in our sources, the Hα line is in emission in TCP J0607 and MASTER J2139. As proposed, based on their large-amplitude early superhumps, this emission profile of Hα also suggests that they are high-inclination system. In the literature, WZ Sge, the early superhump amplitude of which is 0.14 mag, showed Hα in emission

Table 3. Strength of He II 4686 Å and amplitude of early superhumps.

Name	Strength of He II 4686Å*	Amplitude of early superhumps (mag)	Reference
ASASSN-20kv	<0.05	0.00	This work
GW Lib	1.03	0.00†	Hiroi et al. (2009)
V592 Her	1.01	0.01†	Mennickent et al. (2002)
TCP J2003	<0.01	0.012	This work
TCP J0059	<0.01	0.016	This work
ASASSN-19ado	1.16	0.016	This work
EQ Lyn	<0.01	0.025	This work
TCP J0607	1.10	0.028	This work
WZ Sge	1.17	0.14†	Nogami and Iijima (2004)
MASTER J2139	1.50	0.189	This work
V455 And	2.60	0.22†	Nogami et al. (2009)
PNV J17292916+0054043	Observed‡	0.015†	vsnet-alert 17327
ASASSN-14cl	Observed‡	0.018†	Teyssier (2014)
V572 And	Observed‡	0.07†	Quimby et al. (2005)
OT J111217.4−353829	Observed‡	0.14†	vsnet-alert 9782
CSS 080304:090240+052501	Observed‡	0.35†	Djorgovski et al. (2008)

*Peak flux strength compared the normalized continuum.
†Taken from Kato (2015).
‡"Observed" means He II 4686 Å emission line was detected, however the strength is not noted.

and other Balmer seiries in absorption (Nogami & Iijima 2004). CSS 080304:090240+052501 and V455 And showed all Balmer lines in emission in their spectra around the optical peak, the early superhump amplitudes of which are 0.22 and 0.35 mag, respectively (Djorgovski et al. 2008; Nogami et al. 2009; Kato 2015). These discussions support the general spectroscopic behavior that a system with higher (lower) inclination tends to show larger (smaller) early superhump amplitude, and stronger (weaker) emission components in Balmer line profiles. We note that one exception in literature is the low-inclined GW Lib (Thorstensen et al. 2002). Even though GW Lib did not show detectable early superhumps (Kato et al. 2009), the spectra within 1 d from the optical peak showed strong Hα emission (Hiroi et al. 2009). However, the Hα emission of GW Lib turned into absorption 10 d later. Therefore, more systematic studies of the spectral evolution across a DN superoutburst are needed to define the relation between the line profiles and system parameters.

5 Summary

In this paper, we present 17 DN superoutbursts observed by the 3.8 m telescope Seimei and the VSNET collaboration. Our findings are summarized as follows.

- Based on our photometric observations through VSNET and using public survey data, 11 of our objects are WZ Sge-type dwarf novae and their candidates, and the other six objects are SU UMa-type dwarf novae and their candidates. 11 systems are newly identified systems in this work. Using the periods of early and ordinary superhumps, we determined the mass ratios of TCP J0059, ASASSN-19ado, and TCP J2003 as 0.103(6), 0.081(5), and 0.109(5), respectively.
- Our spectroscopic observations of 13 objects are performed within 5 d from the outburst peak of their superoutbursts. Moreover, our spectra of six objects are obtained less than 1 d from the outburst peaks and discovery reports. These quick follow-up observations illustrate the capability of the Seimei telescope for follow-up observations of unknown transients.
- In our objects, the emission line of He II 4686 Å is detected among ASASSN-19ado, TCP J0607, and MASTER J2139, which show large-amplitude early superhumps. Combining nine WZ Sge-type DNe which have early superhump amplitudes and spectra during the early superhump phase that are available in previous studies, our result suggests that the higher the inclination of system, the stronger the emission line of He II 4686 Å, as with the amplitude of early superhumps.
- Using our sources and previously reported spectra of WZ Sge-type DNe taken within 1 d of the outburst peaks, we examined a general correlation among the spectra in the early phase of WZ Sge-type dwarf novae. The supported correlation is that a system with higher (lower) inclination tends to show a larger (smaller) early superhump amplitude, and stronger (weaker) emission components in the Balmer series.
- AL Com showed an outburst in 2019, which is only 4 yr later than the less energetic SU UMa-type superoutburst

in 2015. Our photometric observations confirmed that this 2019 outburst is a WZ Sge-type DN superoutburst, based on the detection of early superhumps.

- We reported the observations on the second outburst of PQ And in observed history. Our observation detected the plateau phase of the main superoutburst and long-duration rebrightening with a 2 mag dip, supporting its classification as a WZ Sge-type DN.
- MASTER J2348 is confirmed as an EI Psc-type DN based on the detection of the Hβ absorption line, the superhump period of which is below the period minimum. This classification is consistent with the suggestion given by Kato et al. (2014).

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Supplementary data

The following supplementary data is available on the online version of this article.

Tables E1–E26.

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